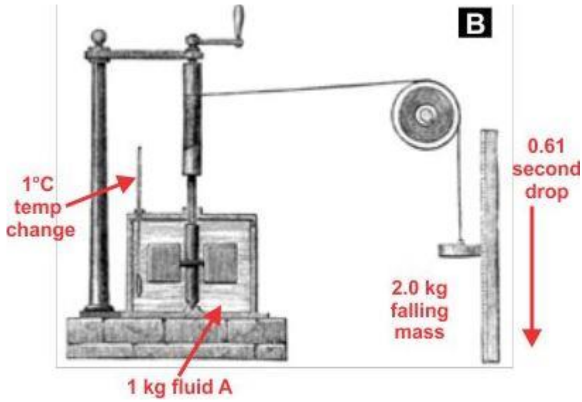


How Joule Accidentally Measured Heat Impulse

Professor Du-Ane Du

www.Wacky1301SCI.com, *"Looking at serious science, sideways!"*

Three sisters, Pico, Hectii, and Tera, the "Space-sci Sherlocks," are traveling through the Asteroid Belt. They discover how Joule accidentally measured heat impulse when he was doing his heat-is-work experiments!
—Excerpted from *Murdered Energy Mysteries*, Part 3, Chapter 2, by Du-Ane Du, (Amazon, Kindle, ebook 2018, paperback 2021).

Are there other conservation laws?" Tera queried.

"Yes, in 1783 and 1789, a scientist named Antoine Lavoisier proposed two new conservation laws. One was the law of conservation of mass, and the other was the conservation of heat-calories," Grandpa Proge said. "These two laws became the foundation for the science of chemistry."

"I'll get the ice cream," Tera sang out.

"Keep going, Grandpa," Hectii said. "This is fascinating."

"Lavoisier proposed that *caloric* was a fluid-like substance that flowed from one object to another," Proge elaborated. "A hot object contained lots of caloric, and caloric flowed from a hot object to a cold object."

"Kind of like how an impulse transfers atomic momentum from one place to another?" Hectii solicited. "In the rocket-fuel experiments, the impulse moved atomic momentum moved to the surface of the rocket engine, then the momentum was transferred from one atom to another and allotted and distributed throughout the mass of the rocket."

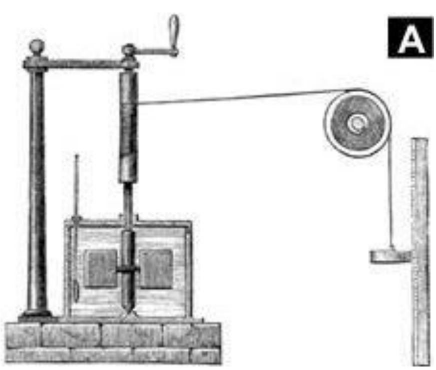
"The transfer of momentum from one place to another is similar to a fluid behavior!" Pico said. "Good observation, Hectii."

"The original idea of caloric was that it was like a gas that had no mass," Proge said. "It was never connected to the idea of impulse/momentum-transfers."

"Too bad," Hectii said disappointedly. "I liked the idea that calories are the same thing as heat-related atomic momentum. That way the conservation fact for r-s-t momentum would be the same as the law of conservation of calories."

"But no one made that connection," Tera countered. "What came next?"

Proge smiled knowingly. "One of Dalton's students was a man named James Prescott Joule. Joule did experiments with special mixer. As a weight dropped, the mixer stirred a container of water, and the water became warmer."



"It's a gravity motor!" Hectii said proudly. "That means heat is related to gravitational momentum-impulse!"

"How can you tell?" Pico said.

“Look at the right side of Joule’s equipment,” Hectii said. “Gravity gives downward momentum to the atoms in the weight, the weight forces the momentum into the atoms in the rope, the rope forwards the momentum to the atoms in the axel and mixer, and the mixer forces the momentum into the atoms of water.”

“In other words,” Tera paraphrased. “The gravitational momentum in the falling weight is transferred to the atoms in the water, where it becomes atomic momentum—and that causes the temperature of the water to rise!”

“That means I was right,” Hectii said triumphantly. “Atomic momentum and heat-calories must be related!”

“Wouldn’t that depend on the equations they used?” Pico said. “Grandpa, did Joule time how long the mixer turned, or did he measure the distance that the weight fell? If he measured the distance, did he remember to use the square root equation for Gravitational Potential Distanced Impulse?”

Proge shook his head. “Joule was trying to prove that heat is a form of work. While he did time some of his experiments, for the most part, Joule measured the distance that the weight fell—and he didn’t use the square root equation.”

“Sound’s a lot like the work-done experiment we did yesterday, you remember lifting the bricks,” Tera said as she burst into song:

We -e -e -e -e
Work'd our impulse, Did it speedy,
Making speedy impul -l -l -l -l -l -lse,
'Cause that's what work-done is—!

"Wait, that's my song," Pico protested. "Grandpa, why was Joule trying to prove heat is a type of work or energy?"

"Joule's experiments began years earlier, when he was a student," Proge replied. "At the time, most scientists believed the movement of electricity from one place to another did not involve the movement of mass. That assumption meant electricity had to be a form of *energia*. In fact, they called it, electric *energia*, because they believed electricity did not involve mass (but the theory was flawed due to the fact that electrons have both mass and momentum).

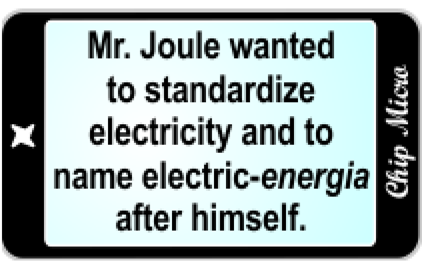
"Joule noticed that when a narrow wire is attached to a battery, the wire gets hot," Proge extended. "So Joule developed the theory that electric *energia* and heat-calories were the same thing—because caloric and electricity both seemed to involve a fluid like substance that had no mass."

"You're saying, heat and electricity are related?" Hectii said.

"Yes," Proge said. "The relationship between heat-calories and electron currents is well established. Both are linear behaviors, and both obey the rules of linear mathematics.

“During the early 1800’s, there was no single standard for measuring electricity,” Proge continued. “Therefore, Joule proposed that electron currents and heat-calories be standardized based on a type of copper-zinc battery invented by a man named Daniell. Joule further proposed that the standard unit of measure for standard linearized electric-*energia* be called a joule. [Basically, (1 volt)(1 amp)(1 sec) = (1 joule[1.2])].”

“Joule wanted to name electric-*energia* after himself!” Tera shockingly said, between mouthfuls of cake. “That sounds very political.”



“Very,” Proge agreed. “Joule had a lot of political influence. But he needed more than just political influence to accomplish his goal. So, Joule developed the Heat-is-Work experiment hoping that he could prove his theory that heat-calories are also a type of mechanical work.”

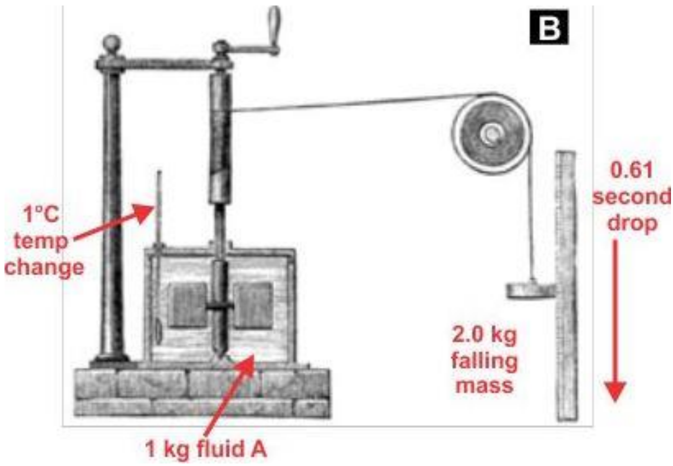
“Joule thought heat-calories are a form of mechanical work?” Hectii said, exasperatedly. “But work-energy involves multi-parabolic kinetic-joules[IC] and work-done involves multi-linear work-joules[IC]! In Joule’s experiment, the farther the weight falls, the faster work-energy accelerates. If you use a different height with each experiment, you'll never find consistent results for how much work-energy is involved!"

"The closest answers Joule ever got involved an error of about 20%," Proge tactfully noted. "For decades, many chemists rejected Joule's theory that heat-equals-work. The biggest objection was probably the fact that the law of conservation of calories was well established by then, and there was no established conservation law for kinetic energy or work energy. Finally, in 1850 a scientist named Rudolf Clauses suggested that if chemists and physicists would accept a law of conservation of standard linearized H&E-joules$_{[1.2]}$, based on the behavior of electricity, then Joule's heat-is-mechanical-energy theory could be merged with the heat-calorie theory."

"I imagine that caused a lot of political conflicts," Pico said softly.

"It was a compromise," Proge said. "It was the century of standardization, and political compromises were being made all the time."

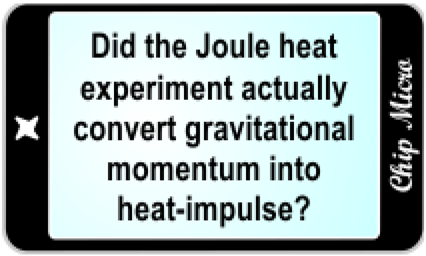
"What about heat-related impulse [momentum transfer]?" Hectii courageously offered. "Here, Grandpa, look at the data I added to your picture:"



"This looks interesting," Tera said, leaning over Hectii's shoulder.

"This diagram shows a 2.0 kg mass being pulled down by gravity," Hectii said. "We've already learned that each second, the Earth's gravity gives 9.8 ρ of downward subatomic momentum to each kilogram of the falling mass. If there's no acceleration, the rope will force the new momentum into the mixer at a rate of (9.8)(2), or 19.6 momentums per second. In 0.61 s, the mixer will transfer (0.61)(9.8)(2) or 12 ρ of momentum into the atoms of the fluid."

"And the additional momentum caused the temperature of the fluid to go up 1.0 degree Celsius," Pico interpolated. "That suggests heat involves the transfer of atomic momentum from one object to another—which'd make heat a type of impulse [momentum transfer]."



Hectii grinned victoriously. "The more momentum you add to the fluid, the higher the temperature."

"Now it looks like both heat and temperature are somehow related to the transfer of momentum from one object to another. That would make heat a type of impulse/momentum-transfer," Pico said. "But James Prescott Joule and other scientists thought heat and temperature are related to molecular kinetic energy."

"It's too bad Joule didn't use a stopwatch during his experiments," Tera said regretfully.

"Actually, Joule did," Proge advanced. "In his most accurate published experiment, Joule used a clock to calculate the speed that the weight was falling. He determined that the weight fell at a constant speed of 1.0 foot per second, which was a common experimental speed at the time."

"Why did he want to know the speed that the weight fell?" Pico asked.

"Notice that Joule's experimental apparatus has a hand crank attached to the paddle that churned the water," Proge pointed out. "The weight only fell a few feet. Once Joule had a good estimate of the speed that the weight was falling, he cranked the paddle at the same speed."

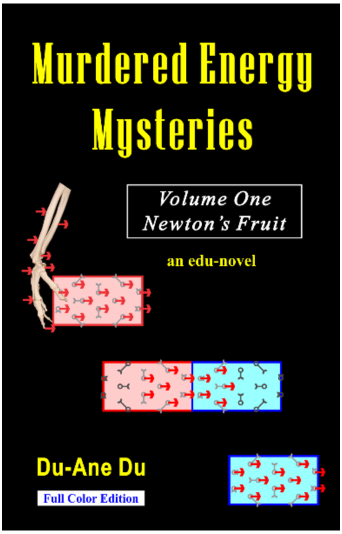
"How long did he turn the crank?" Tera said.

"900 seconds," Proge said. "Since the speed was 1.0 foot per second, Joule multiplied the time by the speed to calculate a distance of 900 feet. He used this distance to calculate the number of foot-pounds of multi-linear work-done—"

"Grandpa!" Hectii said hurriedly. "If we know the speed, distance, and time, maybe we can do a reverse calculation!"

"A what?" Tera said, confused.

Excerpted from:



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"Don't you understand? This version of the experiment involved a constant velocity, *not an acceleration!*" Hectii said, as she began keying information into her phone.

"We forgot all about Pico's fact #1 of work-impulse expansion," Pico commented (*Murdered Energy Mysteries,* Part 3, Chapter 1).

"Great point," Hectii said. "Pico's fact #1 of work-impulse expansion tells us, multi-linear work-done is a scalar expansion of the amount of impulse used…"

"And the variable of scalar expansion is the average speed at which the work was done," Pico meticulously completed.

"Fabulous," Tera said, as her eyes widened with understanding. "We know the velocity that Joule used, and if we apply Pico's fact, then we can calculate the amount of impulse that Joule used."

"Exactly," Hectii said. She walked to the computer, slipped her athletic fingers into data-input ball, and began keying. "The question we're looking at is, does heat involve atomic momentum-transfer (im$\Delta\rho$)? It appears that Joule's heat-is-work experiment involved this equation:"

(*mass of water*)(*joules/g*) = (*F*)(*distance*)
appeared on the display.

"Which means?" Pico said.

"If this were a heat-is-impulse experiment," Hectii said, "then the equation would've been:"

(*mass of water*)(ρ/*g*) = (*F*)(*time*)
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"But we don't know the mass of the water," Tera said regretfully. "We also don't know the mass of the falling weight, or the ρ-force-rate—this is impossible!"

Proge lifted a brow encouragingly, “You don’t always need every piece of information to solve a problem. Remember Pico’s fact?”

Pico nodded as she quickly thumb-keyed information into her phone, “Pico’s fact is the fastest way to convert joules$_{[IC]}$ of work-done into ρ of impulse. The formula is:”

$$work\text{-}done_{[1/S]} = (speed)(im\Delta\rho)$$

$$im\Delta\rho = \frac{work\text{-}done}{speed}$$

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“Grandpa, Joule’s experiment was all about the specific heat of water,” Hectii recalled. “You said his experiment produced an incorrect answer, was it higher or lower than the standard unit?”

“Joule was using English units,” Proge clarified. “He was looking for a measurement of 778 foot-pounds, but his experiment produced a value of 900 foot-pounds.”

“Which means his value was higher than the standard number,” Tera deduced. “Chip, what would that be in metric joules$_{[IC]}$?”

“The calculations for the modern metric equivalent to Joule’s experiment would be:”

$$Joule\text{'}s\ experiment = (Goal)\left(\frac{[actual\text{-}distance]}{[desired\text{-}distance]}\right)$$

$$Joule\text{'}s\ experiment = (4.184\ J/cal)(900/778)$$

Joule's experiment = 4.840 J/cal

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"Joule's experiment would have shown that 1.0 calorie is equal to 4.840 joules[1.2]," Hectii read. "In our Pico's fact experiments, we found that 1.0 J is the same thing as 1.0 ρ(m/s)."

"And to find the ρ of impulse involved," Pico said logically, "all we do is divide by the velocity."

"Grandpa said James Prescott Joule turned the crank at a velocity of 1.0 foot per second," Tera said. "What's the metric equivalent of 1.0 foot, Chip?"

"Does it matter?" Proge said, with a soft chuckle. "Think about it girls—if I'm not mistaken, you're about to discover a new Space-sci Sherlock's scientific fact."

"Think carefully, Sisters," Tera suggested warily.

"Grandpa said, Joule turned the crank at a speed of 1.0 foot per second," Pico said. "That's an old English unit. The other unit he mentioned was 778 foot-pounds."

"Grandpa, what does foot-pounds measure?" Tera said.

"Work-done and work energy, depending on the situation," Proge said. "What happens if you use English units in your Pico's law equation, Hectii?"

"I think it would look like this:"

$$im\Delta\rho = \frac{work\text{-}done}{velocity}$$

$$im\Delta\rho = \frac{778\ foot\text{-}pounds}{1\ ft/s}$$

$im\Delta\rho$ = 778 pound-seconds

appeared on their displays.

"Look at that," Pico exclaimed, "The numbers didn't change—only the units. Joule's experiment involved 778 foot-pounds, and it involved 778 pound-seconds. The numbers are identical!"

"It's an equivalency point!" Hectii said. "Grandpa is right, there should be a scientific fact hidden somewhere."

"Whenever the speed is 1 unit per second," Pico realized. "The numerical value of work-done and the numerical value for impulse-used are identical—but in a way, we already knew that."

"Joule was doing his experiment at the equivalency speed for the old English system of measurement," Tera said. "Does that mean we don't have to multiply or divide?"

"Precisely," Hectii affirmed.

"They're equivalent," Pico said, as she keyed the following into her phone:

Joule's experiment = *4.840 J/cal ≈* ***4.840 ρ/cal***

was written on their displays.

"That's an interesting fact, 1 calorie is equal to 4.840 ρ… but was that his real experimental value?" Tera challenged. "Grandpa said, Joule was trying to prove that the number was 4.184. Did all of Joule's experiments produce a value of 4.840?"

"Only one experiment produced that value," Proge stipulated. "James Prescott Joule tried thousands of experiments, and this was the only published experiment that came close to his target of 4.184."

"If 4.840 is his closest result, the other experiments must've produced results that were higher than 4.840," Pico postulated. "That means the real value must also be higher than 4.840—another interesting fact. But how much higher?"

"A good experimental error is 2 or 3%," Hectii said. "We could adjust it up some, knowing the other experiments were higher…"

"And make a range of plus or minus about 1%," Pico said, as her thumbs adeptly keyed. "That way we would be saying that the value is between 1, 3, maybe 4% higher than the value produced by Joule's experiment. How's this look:"

1 cal = (4.840 ρ)(102.44%)
1 cal = 4.958 $\pm$0.04 ρ
was written on their displays.

"Marvelous job, girls, you found the scientific fact," Proge lauded. "I'm the proudest grandfather in history! This experiment by Joule was unique because he used a hand crank and a clock. The hand crank produced a constant force and a constant velocity. There was no acceleration during this particular experiment. Your conversion works because Joule used a fixed experimental velocity."

"And the math was easy because Joule used a speed of 1.0 foot per second—which is the work-to-impulse equivalency speed for English units," Pico said.

"We need to codify this fact," Tera nominated. "Let's call it **Joule's double-meaning fact of heat-impulse**."

"I love it," Pico said winningly.

"We'll begin by noting that Joule's most successful heat experiment didn't involve gravitational acceleration," Hectii said.

"Joule's best experimental results occurred when he turned a hand-crank with a force of 1.0 lb, a speed of 1.0 ft/s, for 900 seconds," Pico said.

"Because he used a clock!" Tera said. "By using a clock, Joule was actually measuring the amount of impulse needed to raise the temperature of the water."

"However," Pico said. "Because the speed was 1.0 ft/s, Joule multiplied his measurements by the speed to find a value he associated with multi-linear work-done."

“Look at this,” Hectii said, holding her phone for all to see. “I calculated the three conversion equalities that relate to Joule’s double-meaning fact of heat-impulse:”

1 cal of heat = 4.958 ±0.04 ρ of heat-impulse
1 $J_{[1.2]}$ of linear heat = 1.185 ±0.009 ρ of heat-impulse
1 ρ of heat-impulse = 0.202 ±0.002 cal
was written on their displays.

“Now I’m a little confused,” Pico articulated. “Are linearized H&E (heat & electric) $\text{joules}_{[1.2]}$ the same thing as kinetic energy, or are linearized H&E-$\text{joules}_{[1.2]}$ a form of impulse?”

Tera raised a quizzical eyebrow, “Could both ideas be true?”

CONCLUSION: More research needs to be done into the relationship between mechanical energy and other theoretical forms of energy. Many common beliefs may actually be philosophical myths.

Murdered Energy Mysteries seeks to increase understanding of the various forms of momentum and momentum transfer, as well as the various forms of energy and energy transfer. The lack of understanding on the part of the scientific community is substantial, and more research needs to be done.

—Du-Ane Du, author of the edu-novel *Murdered Energy Mysteries* (Amazon, Kindle, e-book 2018, paperback 2021.)

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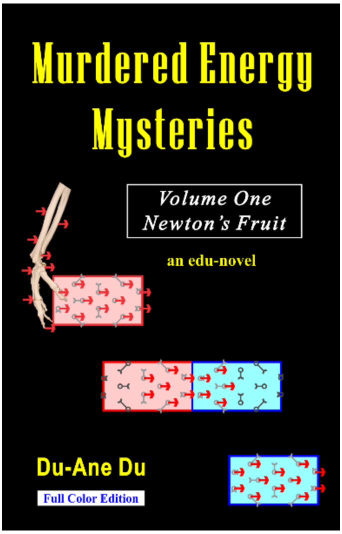

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